CORRELATION OF INTRAOPERATIVE RECORDINGS FROM A FOREHEAD MOUNTED LIQUID CRYSTAL THERMOMETER AND ESOPHAGEAL THERMISTOR

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DISCLAIMER STATEMENT

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ABSTRACT

This study evaluated the performance of a liquid crystal temperature device during general anesthesia. Eighteen patients undergoing general anesthesia were the study population. After obtaining informed consent, the liquid crystal device was placed on the patient’s forehead in the holding area. Patients were brought to the OR suite where general anesthesia was induced via IV technique and maintained with Isoflurane and N_2O or Desflurane and N_2O. An esophageal stethoscope/thermistor was placed shortly after induction of anesthesia for temperature assessment and correlation with the recordings of the liquid crystal device. One hundred and ninety temperature comparisons were recorded. Statistical analysis using Pearson’s correlation coefficient gave an $R= .653$ significant at the $p< .01$ level. The forehead mounted liquid crystal thermometer appears to be comparable to intraoperative temperature recordings with that of the esophageal thermistor.

Keywords: temperature, liquid crystal device, esophageal stethoscope/thermistor

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PREFACE

This research was performed to evaluate the performance of the *Crystaline Indicator*, liquid crystal temperature indicator by Sharn Inc by comparing it with an esophageal thermistor during the intraoperative period.

DEDICATION

I would like to dedicate this project to my wife and children who have had to sacrifice many hours of time away from Daddy so this project could get completed. We are stronger from the experience.

ACKNOWLEDGEMENT

I would like to extend grateful appreciation to the members of my committee whose help provided me with focus and thoughtful, yet gentle critique.

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CHAPTER ONE-INTRODUCTION

Background of the Problem

The ability to indirectly monitor a patient’s core temperature is a primary concern for the anesthesia provider. During the intraoperative period, placement of a monitoring device for core temperature assessment, ie; a pulmonary artery catheter or esophageal thermistor, may be unsuited to the type of surgery performed. However, fever, hypothermia, and malignant hyperthermia must be detected quickly and interventions initiated promptly and appropriately to avoid serious compromise of the patient. The most common perioperative thermal disturbance, by far, is inadvertent hypothermia which is defined as an absolute core temperature of less than 36°C, (Marsh & Sessler, 1996). Ideally, body temperature could be measured non-invasively from a peripheral site that reflects core temperature. It would be desirable that the both the site and device be readily accessible and the device should possess consistently small offset error and a high correlation to core temperature. Many temperature sensing devices presently exist to monitor a patient’s temperature, ie; tympanic membrane thermometers, bladder catheter thermometers, rectal thermometers, and skin-mounted liquid-crystal thermometers (LCT). Although skin mounted liquid-crystal thermometry is frequently used, significant controversy exists surrounding its accuracy and reliability in monitoring temperatures of patients during the intraoperative period. Gilbert and Vender (1996) acknowledge that liquid-crystal thermometers can monitor skin temperature over a wide range, however, they also assert that they are inaccurate because they are dependent upon good skin contact and minimizing nonpatient thermal influences, ie; the influence of ambient temperature on the device. According to Cork, Vaughan and Humphrey (1983) hypothermia may be difficult to assess using liquid-crystal thermometers placed on skin surfaces because skin temperatures may be anywhere from 1-4°C less than core temperatures. The difference between skin and core temperatures varies considerably both between and within individuals. Vaughan, Cork, and Vaughan (1982) determined in their research that liquid-crystal thermometers were not reliable or valid trend indicators of core temperatures. Imrie and Hall (1990) conclude that body core temperature cannot be accurately derived from measurement of skin temperature from only a single site which is common for liquid-crystal thermometers. Lacoumenta and Hall (1984) found in their study of 20 patients receiving general anesthesia for abdominal or pelvic surgery that liquid-crystal thermometry was an inadequate estimation of core temperature during anesthesia. Other research which has been conducted has drawn similar conclusions about the lack of accuracy measuring core temperature with liquid-crystal thermometers (Darm, Hecker & Rubal, 1994; Ellis, Williamson & White, 1989).

Though infrequently stated in the literature, a few studies concluded that although precise measurement of body core temperature was difficult to determine while using the liquid-crystal thermometers, trending patient's temperatures was statistically reliable using LCT's and therefore was a valuable tool in the armamentaria of the anesthesia provider (Allen, Horrow & Rosenberg, 1990; Brull, Cunningham, Connelly, O'Connor & Silverman, 1993; MacKenzie & Asbury, 1994).

Rationale and Significance of the Problem

Because of the controversy surrounding the use of thermometry during the intraoperative period further research is relevant and necessary. The purpose of this research is to add to the existing knowledge base by comparing a liquid-crystal thermometer placed on the forehead with an esophageal stethoscope/thermistor, the accepted “gold standard” of core temperature measures during the intraoperative period (Allen, Horrow & Rosenberg, 1990; Hayward, Eckerson & Kemna, 1984; Morrison, 1988; Summers, 1991; Webb, 1973).

Mechanisms of Heat Loss

According to Wenger, (1995) the production of heat occurs in all body tissues but loss of heat to the environment is only through those tissues contacting the environment and is mostly from the skin. Heat transfer within the body occurs in two ways: conduction and convection.

Conduction of heat is from tissue to tissue and varies directly with the thermal conductivity of the tissues. Change in temperature over the distance the heat travels, and the area through which the heat flows are also variables. Conduction of heat varies inversely with the distance the heat must travel and in general, tissues are poor conductors of heat. During surgery, however, tissues of the internal body are exposed to the environment and subsequent heat loss can be extreme, especially in areas of high blood flow ie; the thoracic cavity, abdominal cavity and cranial cavity.

Convection refers to the process whereby heat is transferred via the blood stream from areas of warmer to cooler tissues. This method of heat transfer is dependent upon the rate of blood flow and the temperature difference between the tissue and the blood supplying the tissue. The capillary beds, because of their great surface area and thin walls, are the most efficient areas of heat exchange between blood and tissue. Skin blood flow becomes reduced in a cool environment and this in turn changes shell thickness by increasing it. The affected skin becomes cooler, including the underlying tissues as they lose heat by conduction to the cooler overlying skin. Ultimately heat is lost to the environment. The underlying tissues, now cooler as a result of conduction and convection, and which were once part of the warm body core, have now become part of the outer shell.

Wenger, (1995) describe the body as being divided into a warm internal core and a cooler outer shell. The shell temperature is strongly influenced by the environment and because of this its temperature is not regulated to within the narrow limits which the internal core is subject. Thermoregulatory responses do greatly influence the temperature of the shell, specifically the skin, the shell's outer most layer. Shell thickness varies with and is determined by the environment and the body's need to conserve heat. Shell thickness may vary from as little as 1 cm thick in a warm environment to a thickness of several centimeters below the skin when exposed to a cold environment. "The internal body temperature that is regulated is the temperature of the vital organs inside the head and trunk, which, together with a variable amount of other tissue, comprise the warm internal core" (Wenger, 1995). Since the shell lies between the core and the environment, all heat leaving the body core must pass through the shell before being given up to the environment with the exception of heat lost through the respiratory tract which is usually less than heat which is lost through the shell. Skin blood flow in a cool subject is low and thus core-to-skin heat transfer is primarily by conduction. In this situation the shell is thicker and thereby serves to insulate the core since heat flow via conduction varies inversely with the distance the heat must travel. The subcutaneous fat layer also contributes to the insulation value of the shell because the fat layer contributes to the thickness of the shell and because fat's conductivity of heat is about 0.4 times that of either dermis or muscle and therefore is a better insulator. In a warm subject the shell is relatively thin, and thus provides little insulation and the skin blood flow is high, so heat flow from the core to the skin is dominated by convection.

Core temperature varies slightly from one site to another depending on such factors as metabolic rate, blood supply and the temperature of neighboring tissue. The value of 98.6°F (37°C) is given which approximates average core temperature, however this is not to imply that thermoregulation is so precise that it does not allow deviation of even a few tenths of a degree. In fact, time of day (circadian rhythm), the menstrual cycle, heavy exercise and fever all demonstrate that core temperature varies from 37°C and is still normal under the circumstances influencing it. Acclimatization to a warm environment can also cause differences of up to about 1°C in core temperature at rest.

Temperature Monitoring Site Selection

Wenger, (1995) states that when measuring core temperature, a site whose temperature is not biased by environmental temperature should be selected. Sites commonly used clinically include the rectum, the mouth and, occasionally, the axilla. The rectum is well insulated from the environment, therefore, its temperature is independent of the environmental temperature and it is a few tenths of 1°C warmer than arterial blood and other core sites. The tongue is richly supplied with blood therefore oral temperatures under the tongue also tend to be a close reflection of core temperature (0.4 to 0.5°C less than rectal temperature); however, cooling the face, neck or mouth can make oral temperatures misleadingly low. Holding the upper arm firmly to the chest thus isolating the axilla from the environment would also give a reflection of the core however 30 minutes or more would be required for reasonable accuracy.

Heat exchange with the environment occurs almost exclusively at the skin surface as previously stated. Skin temperature is under a variety of thermoregulatory influences such as blood flow and sweat secretions, the temperature of the underlying tissues, and environmental factors such as air temperature, air movement, and thermal radiation. Thus, skin temperature is much more variable than core temperature.

The sensation of warmth or cold are from the many bare nerve endings just distal to the skin surface which are exquisitely sensitive to temperature and provide essential information about the need to conserve or dissipate heat from the core (Gilman & Newman, 1995; Wenger, 1995). These afferent nerve endings are classified as either cold or warm receptors depending on the relation of the discharge rate to temperature. Cold receptors are thin, lightly myelinated nerve fibers and warm receptors are thin, unmyelinated fibers with a slower conduction velocity. Both receptor sets share common features. They both are only sensitive to thermal stimuli and have a phasic response component that is rapidly adapting. It responds only to changes in temperature in a fashion roughly proportional to the rate of change and a tonic response, which refers to its intensity, that is dependent on the local temperature. An example of the phasic response is apparent in our adaption to sudden immersion in the warm water with which we bathe. The sensation of warmth which may be very apparent at first soon fades and a less intense impression of steady temperature remains whereas moving immediately to a cooler shower will produce an immediate sensation of cold that will also fade away.

Over an intermediate temperature range ie; the comfort zone, there is no appreciable temperature sensation. This range is approximately 30-36°C for the small area of skin that is usually exposed to the environment and becomes narrower when a larger surface area is exposed, as for example, when wearing a bathing suit. Outside this temperature range there is a steady temperature sensation that depends on the ambient temperature. Sensation of warmth and cold influence blood supply to the skin and thus contribute significantly to the measured temperature at the skin surface. However, this will not be an instantaneous reflection of the core temperature. Blood flowing toward the skin remains at core temperature until it reaches the skin, then comes to skin temperature as it passes through the skin, and stays at skin temperature until it returns to the core (Wenger, 1995). This is an idealized scenario and may be unrealistic because heat is lost by convection through the blood as it continues to flow to tissues and travels its course to the skin and returns to the core. Also heat exchange with these other tissues is greatest when skin blood flow is low and in such cases heat flow to the skin is much less than could be predicted. Measuring whole body skin blood flow is not possible however it is believed to be several liters per minute during heavy exercise.

A calculated estimate of maximum obtainable skin blood flow is 8L/min. Skin blood flow has a tremendous effect on heat transfer. Sweating also significantly contributes to heat transfer to the environment through evaporation and works synergistically with skin blood flow until a point is reached in which increasing skin blood flow causes little change in skin temperature or dry heat exchange. At that point skin blood flow serves primarily to deliver to the skin the heat that is being removed by evaporation.

Autonomic Nervous System Influence Over Temperature Regulation

The Autonomic Nervous System influences blood flow to the skin by dual vasomotor control (Gilman & Newman, 1995; Wenger, 1995). The vasodilation which occurs during heat exposure depends mostly on sympathetic nervous system input and causes the blood vessels to dilate. Regional nerve blockade and general anesthesia can dramatically influence this response causing inhibition of vasodilation with a regional nerve block and massive vasodilation under the anesthetic effects of general anesthesia. Reflex vasoconstriction which occurs in response to cold and also as part of nonthermal reflexes such as baroreflexes, is mediated primarily through the adrenergic sympathetic fibers distributed widely over most of the skin and reducing the flow of impulses in these nerve fibers allows the blood vessels to dilate. In normal physiology, undisturbed by any anesthetic intervention, vasoconstrictor fibers are the predominant vasomotor innervation and the vasodilation that occurs during heat exposure is largely a result of the withdrawal of vasoconstrictor activity. Physiologic thermoregulation is capable of making fairly precise adjustments of heat balance but is effective only within a relatively narrow range of environmental temperatures. Behavioral thermoregulation on the other hand responds to perceptions of thermal sensation from the environment much more quickly and over a broader range than core temperature or physiologic thermoregulation, and, thus, appears to anticipate changes in the body’s thermal state. This is another phenomena which is lost under the influences of anesthesia.

Central Nervous System Influence Over Temperature Regulation

The central nervous system plays a crucial role in thermoregulation by integration of thermal information from core and skin to maintain core temperature. The majority of input for thermal sensation is via afferent neural pathways to the hypothalamus where much of the integration of the temperature information occurs. The sensitivity of the hypothalamus to mean skin temperature allows its thermal regulatory mechanisms to respond appropriately to mild heat or cold exposure with little change in core temperature, so that changes in body heat content due to changes in environmental temperature take place almost entirely in the peripheral tissues. The skin temperature of someone who enters a hot environment rises and elicits sweating even if there is no increase in core temperature. Conversely, an increase in heat production within the body which occurs during exercise or a febrile state elicits the appropriate heat dissipating response because of a rise in core temperature.

The effects of nonthermal inputs on thermoregulatory responses from the hypothalamus are visible in the emotions which elicit vasodilation and flushing as might occur during a period of embarrassment. Skin blood flow is the thermoregulatory response most affected by nonthermal factors because of its involvement in reflexes that function to maintain cardiac output, blood pressure, and tissue oxygen delivery during heat stress, postural changes, hemorrhage, and exercise.

Other Physiologic and Pathologic Influences Over Temperature Regulation

Other physiologic and pathologic influences may change the thermoregulatory setpoint of the hypothalamus as well. Fever will elevate core temperature at rest, while acclimatizing to heat will increase it, and even the time of day and phase of a woman’s menstrual cycle change it in a predictable cyclic fashion. Minimum temperature occurs at night and the maximum temperature occurs in the late afternoon and can vary from 0.5-1°C. Changes in the thermoregulatory setpoint produce corresponding changes in the threshold for all the thermoregulatory responses.

The effect of local temperature on the skin to change blood vessels is seen in at least two ways. Local cooling potentiates and heating weakens the constriction of blood vessels in response to nerve impulses and vasoconstrictor substances. Another way is seen through the direct action of heat or cold on the blood vessels themselves to cause vasodilation or vasoconstriction respectively independent of nerve input. This local effect is especially strong at ambient temperatures above 35°C, and when skin is warmer than the blood coming from the core, the increased blood flow through the vasodilator effects helps cool the skin and protect it from heat injury. Local thermal effects on sweat glands parallel those on blood vessels. Local heating and local cooling potentiate or diminish respectively, the local sweat gland response to reflex stimulation. Further, intense local heating elicits sweating directly even in the complete absence of neural input.

The heat production and heat loss associated with exercise and fever are quite different from what might be expected. During exercise, increased heat production causes an increase in core temperature and is accompanied by a direct increase in heat loss through mechanisms previously described (conduction, convection and sweating). This process is sustained as long as heat production via exercise is maintained. During a febrile state however, heat production may increase significantly (through shivering) with an associated increase in core temperature but heat loss through the skin is minimized via vasoconstrictor mechanisms and the skin may feel cool to the touch. Thus, heat production need not remain high and in fact returns nearly to prefebrile levels once the fever is established. In this way core temperature is preserved without the continued need for heat production.

Clinical Aspects of Thermoregulation

Clinically, thermoregulation is important because of the presence of fever in many disease states, the effects of many factors on tolerance to heat or cold stress, and effects of heat or cold stress in causing or exacerbating certain clinical disorders.

CHAPTER TWO – FRAMEWORK OF THE STUDY

The theoretical framework for this research is the Roy adaption model (Galbreath, 1985). The basic premise of the Roy model is that the patient or individual is considered an adaptive system. An individual is considered a system because of his or her constant interaction with the environment where exchange of information, matter, and energy occur. Adaption occurs as a result of this interaction as well as the individual’s efforts to maintain integrity. These interactions are characterized by internal and external change. Individuals undergoing any type of surgery under general anesthesia certainly experience some degree of challenge to their adaptive system.

Review of the Relevant Literature

The review of the literature is fairly inclusive and presents contrasting findings sufficient enough to justify further investigation. The review of the literature does not, however, critique the methods of the previous research. It is possible, therefore, that methodological errors exist in previous research and new studies may prove helpful in furthering the understanding of thermoregulation.

Forstot’s (1995) opinion is that the skin surface is not an acceptable site for monitoring core temperature. Anesthetic-induced vasodilation occurs during either general or regional anesthesia. It causes an initial and rapid decrease in core temperature due to an internal redistribution of heat rather than an increased heat loss to the environment.

A comparison of peripheral temperature indicators, including a chemical indicator (LCT) placed in the axilla, to measure core temperature, conducted by Henker and Coyne (1995), determined that the liquid crystal device was found to have no statistically significant difference compared to core temperature.

According to Giuffre, et al, (1995) monitoring temperature for patient evaluation centers on two primary issues of concern. The first is site selection since the commonly available temperature sites are known to differ in temperature in normothermia and to differ even more greatly under conditions of rapidly changing temperature. The second concern of Giuffre is the particular instrument’s reliability and validity. Giuffre also points out that an instrument that measures core temperature at one site needs to be just as reliable as another instrument at some other site in order to be a valid reflection of core temperature.

Research conducted by Bush, et al, (1996) looked at ways to improve quality control in the post anesthesia care unit by developing a hypothermia indicator that by helping avert hypothermia would reduce costs. Bush advanced cost containment by decreasing linen consumption by 26% as well as increasing the awareness of hypothermia among members of the Operating Room (OR) and Post Anesthesia Care Unit (PACU) teams. The significance of the Bush study to the proposed research is to show that monitoring patient’s temperature with a reliable and valid thermometer during the intraoperative period results in cost reduction and increases awareness of the effects of hypothermia among participants in this study.

Krause (1993) investigated the reliability and validity of four temperature-monitoring devices including a skin mounted liquid-crystal thermometer (Crystaline ST, Sharn, Inc, Tampa, Fla). The results showed that the Crystaline ST (liquid-crystal device) performed better in accuracy and response time tests than other devices tested (electronic thermistor and thermocouple temperature-sensor devices). Regression analysis of the reference temperature comparisons showed that although all devices tested had high correlation coefficients, the Crystaline ST was the closest to a perfect correlation with the reference temperatures ($R = .99685$). A temperature controlled steel surface plate was used as a reference temperature source for test comparisons. These tests were conducted in a controlled environment and not on live subjects.

Summary

The purpose of this research is twofold: (1) to determine the reliability of a skin mounted liquid-crystal thermometer, and (2) to determine the validity (specifically the criterion-related validity) of this device for the measurement of human temperature during the intraoperative period.

CHAPTER THREE - METHODOLOGY

Sampling

Following institutional approval, data for this study were collected at Greater South East Community Hospital in Washington DC.

A random sample of 18 patients having surgery under general anesthesia were the subjects for this research. Informed consent was obtained from each of the volunteers. Exclusion criteria included children less than 18, pregnancy, or individuals unable to give informed consent for themselves.

Procedures, & Measurement Methods

The *Crystaline™ Temperature Trend (LCT) Indicator (adjusted for core temperature*) liquid crystal temperature indicator (LOT: Q-005) manufactured by Sharn Inc, Tampa, Fla. was used as the test instrument. The liquid crystal temperature strips were provided probono by Sharn Inc and no other obligations were incurred in this study. This device has been manufactured by Sharn to measure core temperature when placed on the forehead. The manufacturer adjustment is 1.9∞ Celsius or 3.5∞ Farenheit upward from skin temperature to indicate core temperature. This device can be read in either a Celsius or Farenheit scale with a range from 29 to 41 C° in half degree increments and 84 to 106 F° in whole degree increments. The celsius degree scale was chosen for recording purposes.

In a previous study the LCT was compared to three other skin temperature monitoring devices and demonstrated a significant degree of accuracy and the fastest response times to temperature changes. The conditions under which this device was tested in this study, however, were static: a calibrated heated steel plate was the variable temperature source, and room temperature and humidity were maintained at 80°F and 60% respectively, which seldom reflects the typical operating room environment.

To determine criterion-related validity of the LCT being tested, an esophageal stethoscope with attached thermistor was used as the reference for body core temperature. This device has been previously established as a valid and reliable indicator of body core temperature by many authorities (Allen, Horrow & Rosenberg, 1990; Hayward, Eckerson & Kemna, 1984; Morrison, 1988; Summers, 1991;

Webb, 1973). The esophageal stethoscope/thermistor is routinely placed during the administration of a general anesthetic for the purpose of monitoring patient temperature and auscultation of patient heart and lung sounds.

To investigate the reliability and validity of the LCT, the esophageal stethoscope/thermistor was placed in the esophagus at the level which provided optimal breath and heart sounds after induction of general anesthesia. This position is associated with the level of the pulmonary veins between the heart and the descending aorta. One minute was allowed for device equilibration before recording temperatures which was in accordance with manufacturer recommendations. According to Webb (1973) placement of the esophageal temperature device in the previously described position best represents cardiac blood flow and thus core temperature.

Placement of the LCT on the forehead was in the holding area prior to entry into the OR suite in order to allow time for device equilibration. The initial temperature reading from the LCT was made at the same time the esophageal stethoscope/ thermistor temperature was first recorded. Subsequent temperature readings were taken every ten minutes. Both esophageal and LCT temperatures were recorded for comparison for the duration of the surgery. Surgical cases lasting more than one hour but less than three hours were selected in order to obtain multiple recordings. Data collection was conducted only by the author of this thesis.

Protection of Human Rights

Only standard practice which is consistent with the care provided by anesthesia personnel was performed in this study. Patient participation was by written informed consent (see appendix B). Patients participating in this study were identified by a number from one to 18 so that anonymity would be assured.

Statistical Analysis

Temperature readings from the liquid-crystal thermometer and esophageal stethoscope/thermistor were recorded for the same patient. Data were analyzed by the Pearson correlation coefficient which measured the closeness of the relationship of the two temperature readings. SPSS software was utilized for data analysis.

Assumptions

It is assumed that the esophageal stethoscope with attached thermistor would be an accurate reflection of core temperature and that placement of the thermistor was in the lower third of the mediastinum which has been noted to be the correct placement for accurate reflection of body core temperature (Webb, 1973). Another assumption was that the monitor displaying the readings from the esophageal thermistor were calibrated correctly.

Limitations

Possible limitations of this study include the small sample size. Insufficient control on patient selection may be another limitation although there are no current guidelines on whom and when an LCT should be used. Thus, allowing unrestricted selection of patients may provide the best indication of how anesthesia providers are actually using the LCT.

CHAPTER FOUR – ANALYSIS OF THE DATA

Sample

A random sample of 18 patients, having given informed consent, participated in this research.

The patients consisted of 15 females and 3 males between the ages of 27 and 68. A variety of surgical patients undergoing general anesthesia were involved: laproscopic cholecystectomy, laproscopic sterilization, open shoulder arthroplasty, video assisted knee arthroscopy, abdominal hysterectomy, herniography, modified radical mastectomy, lumbar laminectomy, and exploratory laparotomy.

Other observations made included types of warming devices used, specifically; disposable OR head cover, heat moisture exchanger (this device was used for all patients), forced air warmer (upper or lower), and IV fluid warmer.

Specific room temperatures were not recorded. However, all rooms were cool to cold as perceived by this investigator and no initial room temperatures were changed.

All subjects were induced with an IV technique and maintained with Isoflurane plus N_2O or Desflurane plus N_2O.

All patients received fentanyl and midazolam prior to induction. All patients were in the supine position with the LCT placed in the center of the forehead with the exception of the lumbar laminectomy patient. The LCT on this patient was placed to the farthest lateral position of the forehead to facilitate reading the device while in the prone position.

Data Analysis

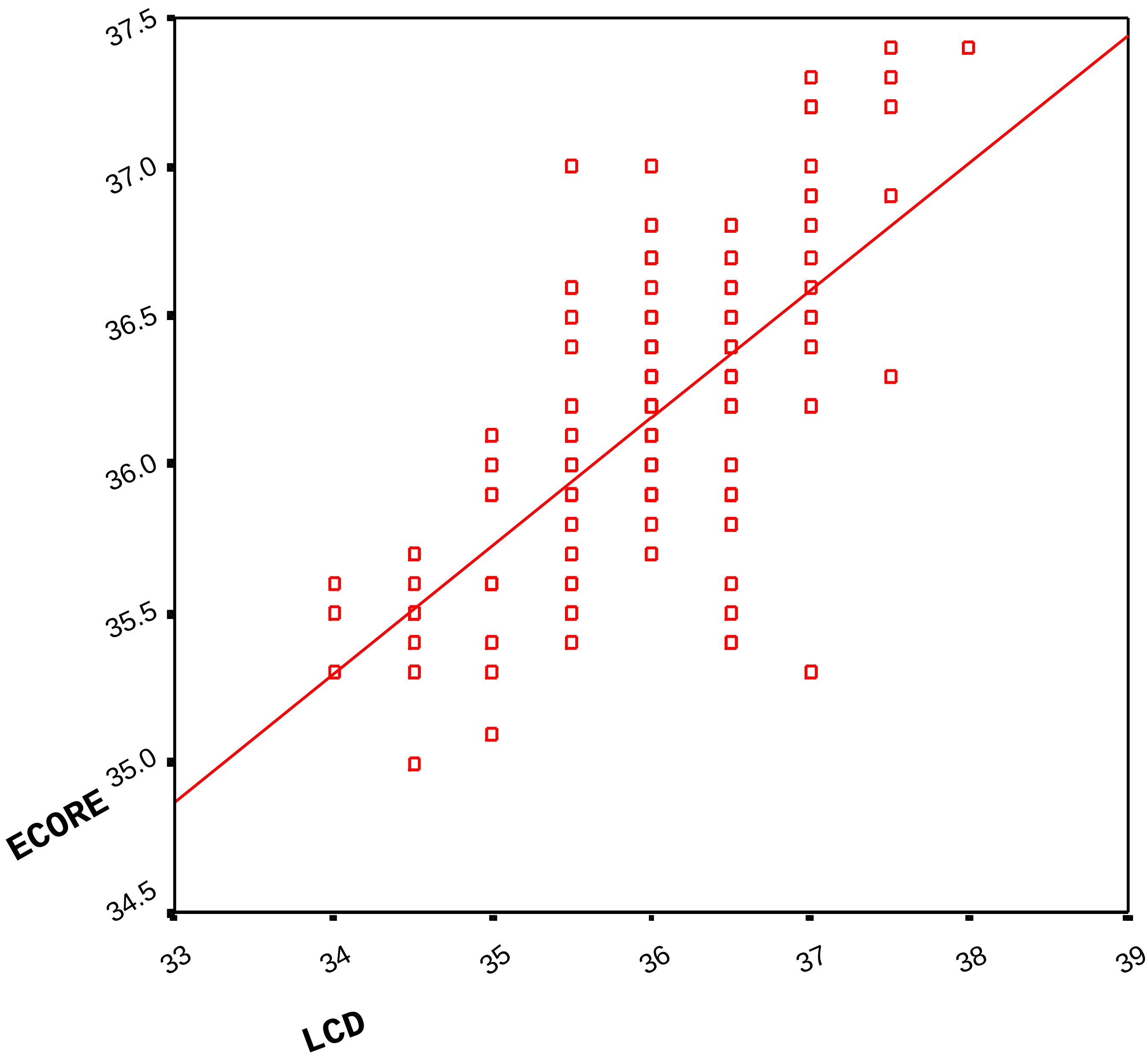
From the 18 patients in this study there were a total of 190 measures of temperature made for the two temperature devices. Minimum and maximum temperatures recorded from the LCT were 34.0 - 38.0 C° (readings were recorded to the nearest half degree). Minimum and maximum temperatures recorded from the esophageal thermistor were 35.0 - 37.4 C° (readings were taken to the tenth decimal place as displayed by the monitor). Standard deviation for the LCT was 0.7516 and standard deviation for the esophageal thermistor was 0.4936 (see table 1).

Table 1. Minimum/Maximum Temperature readings for the variables, esophageal thermistor and liquid crystal device in degrees Celcius for 190 readings among 18 patients.

Minimum/Maximum Temperature Readings				
Device	Range	Minimum	Maximum	Standard deviation
Esophageal thermistor	2.4	35.0	37.4	.4936
Liquid crystal	4.0	34.0	38.0	.7516

A scatter plot representation of the data is depicted in the following graph (see figure 1). The correlation coefficient is 0.653, significant at the .01 level.

Figure 1. Scatter Plot for the Variables, Esophageal Thermistor and Liquid Crystal Device. Pearson correlation coefficient is 0.653 significant at the .01 level.



ECORE = Esophageal Thermistor

LCD = Liquid Crystal Thermometer

CHAPTER FIVE - CONCLUSIONS

Discussion

The purpose of this study was to determine the correlation of temperatures between two temperature recording devices used routinely during an operative procedure when general anesthesia is employed. Temperature monitoring is a standard of care of any anesthetic, and, thus, reliable and accurate monitoring devices must be utilized. The esophageal thermistor is an established gold standard temperature monitoring device and thus served as the control for accurate assessment of patient’s temperatures. The *Crystaline™ Temperature Trend Indicator (adjusted for core temperature*) liquid crystal temperature indicator manufactured by Sharn Inc was the device tested against this gold standard.

Implications of the Results

This study determined a Pearson correlation coefficient of $r = .653$ between the two temperature measures, significant at the .01 level. Research conducted by Brull et. al. using a similar liquid crystal device by Sharn Inc found similar results.

Data indicated that some variability existed between intraoperative temperature measurements obtained from the two devices for the same patients. However, temperature trends, rather than actual temperature values, are more important during surgery. The esophageal thermistor and liquid crystal device trended similarly over time, as evidenced by the consistency of differences between the two devices.

Summary

Assessment of a patient’s temperature during the operative period and into the recovery period is a required standard of care. The esophageal thermistor accurately and reliably provides temperature information during the administration of general anesthesia. However, it is not appropriate for postoperative temperature assessment in the awake patient nor is the esophageal thermistor appropriate for temperature assessment when only sedation is employed as an anesthetic technique. Though minimally invasive as a temperature assessment device, the esophageal thermistor must still be inserted into the esophagus, and, thus, potential for trauma exists or accidental and unrecognized insertion into the trachea.

The LCT evaluated in this research demonstrated acceptable correlation with the esophageal thermistor. Several exceptional features of the LCT include: noninvasive ease of application, hypoallergenicity and latex free construction, convenient dispenser packaging, unit cost compared to the esophageal thermistor, no need for equipment calibration, and application for temperature monitoring in the post anesthesia care unit.

Use of the LCT has application for the military in the field scenario and assists in reducing operative expenses in peacetime. The data collected and analyzed in this study corroborate data from Brull et. al. performed in the early 1990’s. The device evaluated in this research appears acceptable for routine use of temperature trending during general anesthesia.

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APPENDICES

Appendix A

DATA COLLECTION SHEET

	Esophageal Thermistor	Liquid Crystal Device
Initial	________	________
1. 10 min	________	________
2.	________	________
3.	________	________
4.	________	________
5.	________	________
6. 1°	________	________
7.	________	________
8.	________	________
9.	________	________
10.	________	________
11.	________	________
12. 2°	________	________
13.	________	________
14.	________	________
15.	________	________
16.	________	________
17.	________	________
18. 3°	________	________

Patient Demographics

ID#: ________________________________

Age: ________________________________

Sex: ________________________________

Surgery: ________________________________

____

____

Anesthetics: ____________________________

____

Narcotics: ______________________________

____

Beginning room temp:___________________

Warming devices used: (circle
all that apply)
head cover, heat moisture exchanger, forced air warm
(upper/lower body), IVF warmer, warm blanket

Special considerations: _________________

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Appendix B

UNIFORMED SERVICES UNIVERSITY OF THE HEALTH SCIENCES

4301 Jones Bridge Road

Bethesda, Maryland 20814-4799

Subject Title: Correlation of a Forehead Mounted Liquid Crystal Thermometer and Esophageal Thermistor Intraoperatively

Principle Investigator: Jon A. Clark, BSN, Capt., USAF, NC. Capt. Clark is a Registered Nurse with over seven years civilian and military nursing experience. He is currently enrolled as a graduate student in the nurse anesthesia program at the Uniformed Services University of the Health Sciences in Bethesda, MD.

Research Purpose: This study will examine the temperature relationship between a liquid crystal thermometer placed on the forehead and an esophageal thermometer placed in the esophagus during the course of anesthesia. The liquid crystal thermometer will be placed on the forehead in the pre-op holding area prior to the administration of anesthesia and the esophageal thermometer will be placed in the esophagus after induction of general anesthesia and is part of the normal anesthetic course for general anesthesia. This study will in no way effect the anesthesia administered to you.

Foreseeable Risks: This study involves no foreseeable risks or harm to you.

Description of Benefits: Though no specific benefits are expected from your participation in this research, information collected may help direct future methods for temperature monitoring during anesthesia.

Voluntary Participation: Participation in this study is voluntary and you are under no obligation to participate. Fifty volunteers will be used in this research. You may withdraw your consent to participate in this study at any time without any negative affect on the treatment that you are otherwise receiving.

Confidentiality: All information that you provide as a part of this study will be confidential and will be protected to the fullest extent of the law. A number from one to fifty will be assigned to each volunteer and this will be the only means of identification. Data collected will be kept private, accessible only by those persons directly involved in conducting this study, and maintained in a restricted access, locked cabinet while not in use. However, please be advised that under the Uniformed Code of Military Justice, a military member's confidentiality cannot be strictly guaranteed. To enhance your privacy, data will be entered into a database and after verification of database information, all hard-copy material will be shredded.

Questions: Questions regarding any aspect of this study may be directed to Capt. Jon Clark, principal investigator, @ 310-599-2152 or Lt. Col. Michael McCreery, Uniformed Services University of the Health Sciences, Institutional Review Board office @ 301-295-3303.

AUTHORIZATION: I have read this consent form and certify that I am at least eighteen (18) years old. The nature, demands, risks, and benefits of the project have been explained to me. I understand that I may ask questions and that I am free to withdraw from the project at any time without incurring ill will or affecting my medical care. I also understand that this consent form will be filed in an area designated by the Research Committee with access restricted to the Investigators or then authorized representatives. A copy of this consent form will be given to me.

____

Participant’s Signature Date

I hereby certify that to the best of my knowledge the subject who is signing this consent form understands clearly the nature, demands, benefits, and risks involved in his/her participation. No medical problem, language or educational barrier has precluded this understanding.

____

Investigator’s Signature Date